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THE REUSE OF SEWAGE SLUDGE. AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, (137th) MEETING

Federal Water Quality Administration
Cincinnati, Ohio

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AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 137th MEETING

Subject	The Reuse of Sewage Sludge
Author	Robert B. Dean, Ph.D., Chief, Ultimate Disposal Research Program, Advanced Waste Treatment Research Laboratory, FWQA U.S. Department of the Interior
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Incineration of sludge returns only carbon dioxide to the Carbon Cycle. Application of sludge to the land either wet or dry returns carbon dioxide and also returns nitrogen and phosphorus to their respective cycles. Growth of algae on sewage likewise utilizes nitrogen and phosphorus and destroys organic compounds utilizing them only as carbon dioxide. Hydrolysis of sludge using sulfur dioxide, a mild catalyst, dissolves sludge polymers to constituent amino acids and sugars which are the building blocks for all life. The hydrolyzate has potential as a marketable feed supplement for meat producing animals and may be useful for growing cultures of bacteria that produce antibiotics.

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THE REUSE OF SEWAGE SLUDGE

by

Robert B. Dean, Ph.D.

U.S. DEPARTMENT OF THE INTERIOR
Federal Water Quality Administration
Advanced Waste Treatment Research Laboratory
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I

THE REUSE OF SEWAGE SLUDGE

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ABSTRACT

Incineration of sludge returns only carbon dioxide to the Carbon Cycle. Application of sludge to the land either wet or dry returns carbon dioxide and also returns nitrogen and phosphorus to their respective cycles. Growth of algae on sewage likewise utilizes nitrogen and phosphorus and destroys organic compounds utilizing them only as carbon dioxide. Hydrolysis of sludge using sulfur dioxide, a mild catalyst, dissolves sludge polymers to constituent amino acids and sugars which are the building blocks for all life. The hydrolyzate has potential as a marketable feed supplement for meat producing animals and may be useful for growing cultures of bacteria that produce antibiotics.

II

THE REUSE OF SEWAGE SLUDGE*

by

Robert B. Dean**

Direct reuse of water before it returns to the ocean exceeds by far the reuse of any other substance in sheer volume and in monetary value. I refer of course to wastewater that is discharged to our rivers and ground water to be removed later by some downstream community for its water supply. Before wastewater can be reused some of the impurities added by the first use must be removed. Even if the use is only for navigation some of the organic impurities in municipal wastewater must be taken out to avoid putrescent odors. Other uses may require very high degrees of purification.

Removal of impurities from wastewater in sewage treatment plants concentrates the organic matter as sludge of which there are two kinds, Primary and Biological. Primary sludge is obtained by allowing wastewater to settle for several hours and collecting what settles to the bottom of the tank. Biological or secondary sludge consists largely of the bodies of live bacteria which have been grown with oxygen on the organic matter left in primary effluent. In the activated sludge process the bacteria grow in a stirred reactor and collect as clumps or flocs which have a relatively high sedimentation rate. Most of the live activated sludge that then settles out in the final clarifier is returned to the process to feed on organic matter. The excess sludge produced by

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**Dr. Robert B. Dean is Chief, Ultimate Disposal Research Program, Advanced Waste Treatment Research Laboratory, FWQA, Cincinnati, Ohio.

multiplication of the organisms becomes waste activated sludge. The sludge that sloughs off trickling filters is biologically similar to waste activated sludge. Good biological treatment removes over 90% of the degradable organic carbon in wastewater leaving less than 20 parts per million in the effluent. Advanced Waste Treatment can remove over three fourths of the remainder by adsorption on activated carbon and filtration of suspended matter.

Sludge contains in more or less modified form the organic substances which are present in foods including husks and peelings together with other organic substances such as cellulose and detergents. It also contains part of the nutrient or fertilizer elements, nitrogen and phosphorus, that are present in sewage. Chemical precipitation of phosphorus from wastewater may add this element to the sludge but nitrogen is usually removed as a gas.

Conventional sludge treatment starts with anaerobic digestion of both sludges. Bacteria first removes oxygen by respiration producing an anaerobic environment. Other bacteria then degrade organic matter to organic acids and a third group converts the acids to methane and CO_2. In this process about half of the organic matter is converted to gas and much of the combined nitrogen and phosphorus in the sludge solids is dissolved in the supernatant liquid. Anaerobic digestion is controlled rotting and yields a digested sludge that is stable and will not putrefy further. Aerobic stabilization or digestion is an extension of the activated sludge process and converts some organic matter to CO_2.

Digested sludge is usually dried and may be incinerated, dumped in a land fill or recycled by being used as a soil supplement. The fertilizer value of dried digested sludge such as Milorganite from

Milwaukee or the sludge sold by Chicago is low in comparison with synthetic fertilizers and the cost of hauling makes it uneconomical based on its content of nitrogen and phosphorus alone. In today's market the fertilizer value of sludge is less than 1¢ per pound of dry solids. Phosphates from detergents contribute less than one quarter of this value. Removal of phosphates from detergents would reduce the value of sludge but removal of phosphates from sewage in treatment plants would add useful phosphates to the sludge.

The organic matter in sludge resembles humus and sludge does have some additional value in the soil beyond its content of fertilizer elements. The organic portion of sludge that has been applied to the soil is eventually destroyed by microbial conversion to CO_2. The CO_2 re-enters the carbon cycle in the atmosphere only a few months later than it would have done had the sludge been incinerated. None of the organic matter in sludge can be used directly by higher plants but the liberation of CO_2 to the air under the plants may stimulate growth.

Sludge need not be dried before it is put on the land. The soil is a low cost filter and provides large areas for drying. Modern techniques for the bulk handling of liquids and slurries make it more economical to transport wet sludge by pipe line and tanker. Wet transport avoids the cost of dewatering and drying sludge which is a large fraction of the total cost of conventional sludge disposal. When wet sludge is applied there may also be a bonus from its water content in a dry year.

Chicago has been running a daily train of sludge tank cars on the Illinois Central from their Stickney plant to areas near Arcola, Illinois where the wet sludge is spread on the land. Calculations have shown that pipe lines up to 100 miles long would be even more economical than unit trains for sludge transport. There is sufficient low grade land within that distance of every metropolitan center in the country to handle all of the domestic sludge it produces for the foreseeable future.

At this point the usual question is, "If land disposal of sludge is so great, why isn't everyone doing it?" The answer, like anything else connected with sludge disposal, is not easy. In the first place, many smaller places are doing it. In Pennsylvania particularly, where the Pennsylvania Dutch farmers have retained a keen appreciation of the value of the soil, at least 27 plants are spreading sludge. On a small scale it is easy to negotiate with a single farmer to take all the sludge produced. In a larger plant it may be necessary to deal with several farmers and it may be necessary to educate the public to the advantage of sludge reuse. The public relations problem can become very difficult and it may be easier for the sewage plant operator to put in his own incinerator even though the cost is greater than land utilization. It must be recognized that the average citizen has a low opinion of sludge and it is fairly easy to drum up opposition to anything that the big city wants to impose on the countryside.

An estimate of costs of various methods of handling activated sludge was prepared for Chicago in 1967 and has been reported by Dalton et al. (1968). A table summarizing these costs is presented in the next

chapter by Professor Bacon (or as figure attached). Later studies of sludge transportation and spreading have increased some of these cost estimates significantly. The costs for processing by drying, wet oxidation, or incineration are higher than have been quoted for some other plants for a number of reasons. In the first place, activated sludge contains more water and is more expensive to dry than primary sludge. In the second place, Chicago's drier, which has since been shut down, was certainly not as efficient as a modern drier. A reasonable range of costs for drying and incineration of waste activated sludge would be $35 to $45 per ton dry solids. Costs of land disposal will probably range from $25 to $35/ton dry solids for distances of 50 to 100 miles away from the plant. This includes stabilizing the sludge before transport and facilities for storing sludge until it can be put on the land.

Pipelines are only practical if it is possible to sign a long-term lease with a large land holder who will take the sludge and distribute it on his land. Transportation by rail and truck offer flexibility of destination and an opportunity to demonstrate utility and lack of offensive odors and other pollution on a small scale before long-term commitments are made.

Chicago has been running a daily train of sludge tank cars on the Illinois Central from their Stickney plant to areas near Arcola, Illinois where the wet sludge is spread on the land. Calculations have shown that pipe lines up to 100 miles long would be even more economical than unit trains for sludge transport. There is sufficient low grade land within that distance of every metropolitan center in the country to handle all of the domestic sludge it produces for the foreseeable future.

Composting of sewage sludge is a form of aerobic stabilization that is carried out after partial drying. Because most of the water must be removed composting is more expensive than applying sludge in a wet state to the land.

Humus in sludge improves the agricultural value of soil by providing better physical properties and by retaining moisture in dry weather and by neutralizing excess acid or alkali. Wet sludge is particularly effective in reclaiming worn out soils, mine wastes and mineral dumps. Some recent studies here in Chicago have shown that sludge can grow grass on fine-silica sand with a pH above 12 and also on coal mine waste land with a pH of 3. In the absence of sludge these "soils" would lie barren for years. Sludge also holds down fine sand particles and prevents their being blown about in the wind. Blowing particles would otherwise destroy tender seedlings and prevent the establishment of plant cover on eroded land.

The possibility that disease might be transmitted by wet sludge applied to the land cannot be entirely discounted, even though no communicable disease has been traced to treated sludge that has been properly

applied to the land. Some countries require pasteurization of sludge before it is applied to land during the grazing season although it is recognized that animal wastes contribute more bacteria than does domestic sludge. Pasteurization can be done economically when required. Alternatively lime treatment can provide disinfection at a cost competitive with pasteurization. The lime also increases the agricultural value of the sludge and helps to neutralize toxic effects of heavy metals.

In spite of all the advantages of sludge as a fertilizer and soil conditioner its use for this purpose is very inefficient recycling. There is only a minor contribution from the high polymers that have been produced at the expense of the energy of growth. There is no utilization of the amino acids including those essential ones that cannot be synthesized by higher animals and are the limiting nutritional factor in many diets. Using sludge for fertilizer is analogous to using milk for bathing - it may be effective but it does not fully utilize the values in the fluid.

Municipal sludge contains proteins, carbohydrates, fats and vitamins which are chemically similar to the substances used in animal feed. Indeed they have the same origin and it would be difficult to distinguish between dried primary sludge and many animal feed supplements from their proximate chemical analyses. Activated sludge consists of the bodies and capsules of single cell organisms which differs qualitatively only slightly from the cell mass produced by yeast cultures.

Torula yeast can be grown on the soluble sugars remaining after wood pulping and has been used as a feed supplement. Protein extracted from yeasts grown on petroleum hydrocarbons has been hailed as an answer

to the growing worldwide protein shortage. Single celled microscopic algae are another source of protein which can be grown on sewage. Algae, like land crops, utilize only the mineral nutrients and CO_2 from sewage and do not take advantage of the inherent food values of the sludge.

All forms of single cell protein have limitations when it comes to animal feed. Some early experiments instigated by Hurwitz in Chicago showed that dried activated sludge could be used as a feed supplement for chickens, pigs, steers and sheep. Sludge is a valuable source of Vitamin B-12 even though it is present at only 2 to 4 parts per million. Unfortunately some unknown factors limit the utilization of activated sludge to not more than 4% of the diet of meat producing animals.

One factor which may limit the acceptability of dried sludge as a feed is the high content of non-digestible polysaccharide slimes in the bacterial capsule. Another factor is the bacterial cell walls which must be non-digestible to protect the bacteria. The cell walls consist of polymeric substances like chitin which are built up of amino acids and sugars. If we could hydrolyze sludge completely we could release all the amino acid and sugar monomers in a soluble form in which they would be available for nutrition.

An attempt to hydrolyze sludge has been made by the FWQA under contract with a chemical consultant firm, Foster D. Snell, a subsidiary of Booz-Allen Hamilton of Chicago. They followed a procedure already used by the meat packing industry to dispose of scraps, namely pressure cooking in the presence of sulfur dioxide. It was already known that

pressure cooking of sludge made the sludge easier to filter because it hydrolyzed the polysaccharide slimes. Pressure cooking also releases amino acids to the liquid fraction.

SO_2 provides a favorable pH for hydrolysis so that it proceeds at a lower temperature than in its absence. SO_2 also protects amino acids and sugars from oxidation and inhibits the "browning reaction" between them. Hydrolysis with SO_2 yields an easily filterable solid fraction and a liquid "soup" that is rich in amino acids and sugars. The solid fraction can easily be dewatered to the point where it can be incinerated. It is sterile and non-putrescible and can also be used as a plant mulch.

Most of the nitrogen and phosphorus in the sludge are concentrated in the liquid soup which also contains amino acids and sugars and most of the added sulfur dioxide in a combined form. Amino acids and sugars are the basic building blocks of all plant and animal polymers, proteins and carbohydrates. Those extracted from sludge are chemically indistinguishible from the same compounds present in extract of beef and extractable from any food stuff.

The filtered soup from hydrolyzed sludge has been evaporated to an organic molasses containing 40% solids which resembles other by-product molasses such as beet and wood molasses. Analyses showed a good representation of the nutritionally valuable amino acids, see Table I. Feeding tests with rats showed that supplements of organic molasses produced more efficient utilization of food than the control diet. This means

that the animals used less food for a given weight gain, see Table II.

The preliminary work is being followed up with tests on a larger scale and with primary as well as activated sludge. The economics of evaporation depend critically on the solids content of the sludge fed to the pressure cooker and preliminary estimates of 1.5 cents a pound in the original report are probably over optimistic. Never the less, it may be possible to make a small profit from sludge disposal and at the same time help the protein shortage and reduce the cost of meat products. It also has potential as a component of nutrient broth for industrial fermentation and antibiotic production.

One inevitably will ask whether the amino acids and sugars extracted from sludge might be used for human food. The answer is probably no - not necessarily for aesthetic reasons but also because man who is historically a carnivore probably cannot tolerate a diet high in microbial products.

The limitations of microorganisms as food sources for man have been highlighted by recent studies supported by NASA. Plans for extended manned flights to other planets have forced a consideration of ways of recycling the elements in human waste to conserve weight. The principal component of these wastes, after water, is CO_2. One of the schemes employed a culture of bacteria, Hydrogenomonas, which is closely related to the bacteria in activated sludge. Hydrogenomonas grows on hydrogen and CO_2 converting them to cell mass. Hydrogen can be obtained electrolytically from water along with oxygen which is necessary for human life. If the Hydrogenomonas could be used as food for the astronauts we would

have a beautiful closed cycle including food, air and water driven of course by external energy, this time in the form of an electrical current.

Unfortunately, the Hydrogenomonas proved to be wholly unacceptable as a food. Its presence in human diets caused severe gastric disturbances even though animal feeding tests had been acceptable. Rats, chickens and pigs commonly used as test animals consume fecal matter containing masses of bacteria in their natural diet. Ruminants such as sheep and cattle maintain their own cultures of anaerobic bacteria in their rumen to break down cellulose. The excess bacterial mass then provides nourishment to the animal. The natural presence of microorganisms in the diets of meat producing animals should make them more tolerant of the bacterial factors which are limiting for humans. At the present time there should be no consideration given to inclusion of bacterial hydrolyzate in human diets.

Even though sludge bacteria cannot be used as a source of human food their utilization as animal feed is an efficient form of sludge recycle and can help improve the world's supply of preferred proteins. No trace of the genetic source of the amino acids could survive SO_2 hydrolysis since DNA and RNA would also be hydrolyzed. The constituent amino acids will carry no more information about their origins than does a pile of reclaimed bricks from an urban renewal site.

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TABLE 1

AMINO ACID ANALYSIS OF ORGANIC MOLASSES

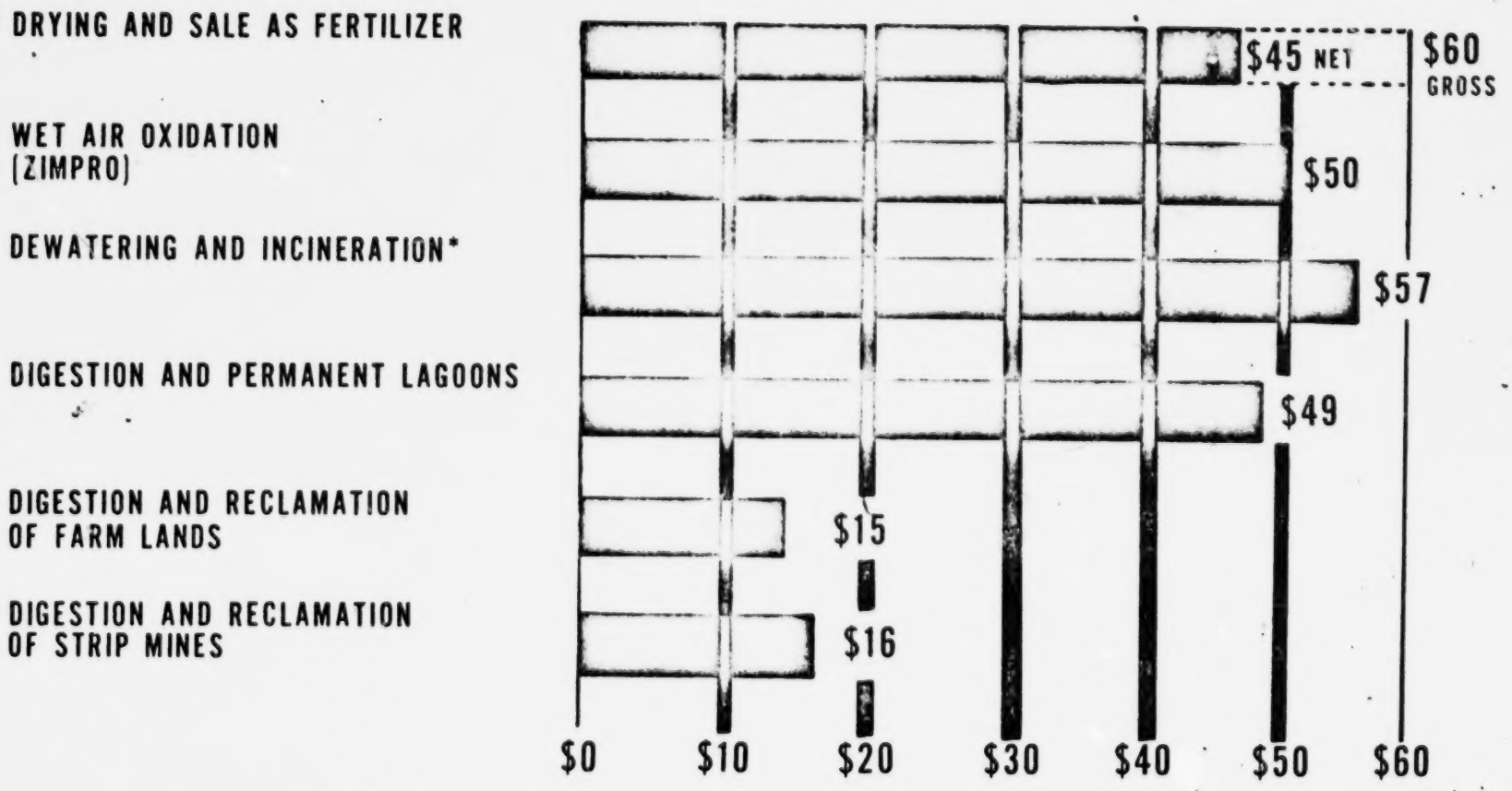
1.	ARGININE	0.79%
2.	CYSTINE	0.17
3.	GLYCINE	1.88
4.	HISTIDINE	0.37
5.	ISOLEUCINE	1.08
6.	LEUCINE	1.01
7.	LYSINE	0.87
8.	METHIONINE	0.36
9.	PHENYLALANINE	0.74
10.	THREONINE	1.13
11.	TRYPTOPHAN	0.23
12.	VALINE	1.37

TABLE 2

RAT FEEDING 21 DAY

	WEIGHT GAIN	FOOD CONSUMED	EFFICIENCY
CONTROL (Sucrose)	132	402	33%
ORGANIC MOLASSES 5%	122	343	35%
ORGANIC MOLASSES 10%	144	344	42%

COSTS OF DISPOSAL METHODS FOR ACTIVATED SLUDGE



*Preceded by High Rate Digestion